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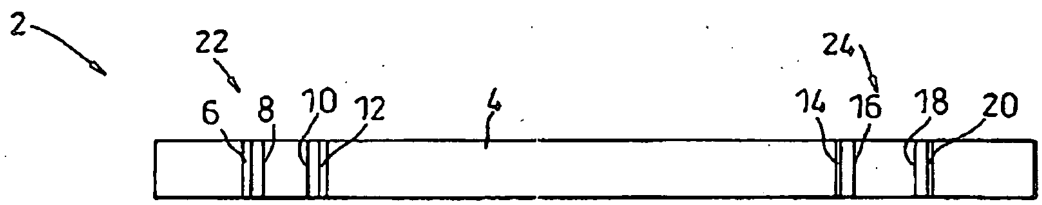
(54) **Title:** INTRACAVITARY IMPEDANCE MEASURING PROBE



(57) **Abstract:** A device for measuring conductance within a lumen containing conducting medium and having an average diameter, the device comprising: a body portion positionable within the lumen and having a body diameter; drive means; a sensor driven by the drive means comprising: means for applying a first electrical current across a first distance substantially equal to the body diameter; means for applying a second electrical current across a second distance, the second distance being greater than the first distance; sensing means for sensing the voltage across both the first and the second distance; means for measuring the impedance across both the first and second distances, and means for comparing the impedance across the first distance with the impedance across the second distance.

WO 03/092495 A1

INTRACAVITARY IMPEDANCE MEASURING PROBE

This invention relates to a device for monitoring conditions within a lumen within a human or animal body. The invention relates particularly to a device for measuring conditions within gastro-intestinal, urological, neurological and rectal tracts.

It is known that the measurement of impedance within a lumen can be a useful tool for indicating the presence of an organ or fluid in the region surrounding the device taking the measurement. In a known application, the impedance is measured using either DC or AC techniques.

Mary, North and Hunt describe in the Am. J. Physiol 236(5), E545-E549, 1979 an oesophageal probe and apparatus in which current of 30 μA at a frequency of 350 Hz is injected into an outer pair of co-axial annular silver/silver chloride electrode assemblies. A variable voltage output from an inner pair of electrodes, directly proportional to inter-electrode impedance, is then measured. A plurality of electrodes are equally spaced along a catheter and measurements are taken in a sequential substantially simultaneous manner by indexing one electrode at a time to take measurements along the length of the catheter.

Although only a single frequency is employed in this system, it is also known to use multiple frequencies to investigate systems exhibiting mixed electronic and ionic conductivity.

The data obtained is interpreted using complex plane analysis. The real and imaginary parts of the conductance are plotted against each other as a function of frequency. This allows an equivalent circuit with lumped

resistance and capacitance to be established, the individual elements of which can be correlated with physical processes. The same approach can be applied using time resolved methods (simplified Fourier transforms) by exciting the system with a square wave current and observing the exponential decay of the voltage in discrete time windows.

Known investigations into gastrointestinal function can include, for example, measurement of pH and pressure variation in the oesophageal body between the upper and lower oesophageal sphincter. "Practical Guide to Gastrointestinal Function Testing" by Charlotte Stendal (Blackwell Science, 1997) describes a system in which sensors are mounted on nasally or orally intubated catheters.

pH sensors are conventionally deployed in combination with oesophageal manometry that measures the function of the oesophageal body muscle and its sphincters by obtaining pressure profiles. 24 hour pH monitoring facilitates the diagnosis of oesophageal acid exposure. It involves the trans-nasal placement of a pH sensor located 5 cms above the manometrically-identified lower oesophageal sphincter (LES). The sensor monitors changes in intra-oesophageal pH over a circadian cycle by logging data into an ambulatory recording device.

This technique is, however, of limited use for diagnosing gastro-oesophageal reflux disease, or as a first line investigation in patients with dysphagia or chest pain.

A problem with known devices for monitoring conditions in a lumen by measuring impedance is that the devices work on the assumption that conditions at the surface of electrodes forming the devices remains constant. This, however, is not the case when sensors are positioned within a lumen

containing, for example, refluxate. This means that measurements using known devices do not accurately reflect the impedance of the media between the electrodes.

Another problem with known devices, is that in order to measure more than one parameter within a lumen, the device often has to be relatively large in order to incorporate a different sensor to measure different parameters. The resulting device can be very difficult to insert into a lumen within a human or animal body.

According to a first aspect of the present invention there is provided a device for measuring conductivity within a lumen containing conducting medium, the device comprising:

a body portion positionable within the lumen and having a body diameter;

drive means;

a sensor driven by the drive means comprising:

means for applying a first electrical current across a first distance substantially equal to the body diameter;

means for applying a second electrical current across a second distance, the second distance being greater than the first distance;

sensing means for sensing the voltage across both the first and the second distance.

means for measuring the impedance across both the first and second distances, and

means for comparing the impedance across the first distance with the impedance across the second distance.

Preferably, the first distance is small compared with the dimensions of the lumen.

Advantageously, the drive means produces a drive waveform.

An important piece of information often required by clinicians, is an estimation of the nature and volume of any refluxate in a lumen such as the oesophagus. Knowledge of these parameters, and how they vary over time, as a function of the effects of medication and after eating, will improve the accuracy of diagnosis, particularly of gastro-oesophageal reflux disease, and enhance the efficacy of treatment.

By means of the present invention it is possible to determine not only the presence of a medium in a lumen, for example a refluxate in the oesophagus, but also the amount of medium present.

In use, the second distance is substantially equal to the diameter of the lumen in which the device is inserted, and the first distance is substantially equal to the diameter of the body portion.

Advantageously, the means for generating the first and second electrical currents comprises first and second pairs of drive electrodes, the electrodes forming each of the first and second pairs being separated by the first distance, and the first and second pairs being separated by the second distance.

Preferably the body portion comprises a catheter. A catheter may be conveniently inserted into a lumen in a human or animal body. For example if the device is to be used to measure conditions within the oesophagus, the catheter may be inserted into the oesophagus via the mouth or nose of a patient.

The first distance is preferably comparable with the diameter of the catheter and the second distance comparable with that of a distended lumen.

Preferably, the sensing means comprises a voltage sensing electrode associated with each drive electrode.

A pair of sensing electrodes is thus positioned between each pair of drive electrodes to detect the voltages generated by the passage of these currents.

The use of a separate voltage sensing electrode associated with each drive electrode as described herein above reduces problems associated with changing conditions at the surface of the drive electrodes.

It is known that the conductance of a medium is proportional to the cross-sectional area of the medium between the electrodes measuring the conductance, provided that the current flow is uniform over that area. Thus if the conductivity of the medium is known the cross-sectional area can be estimated.

Within a medium of substantially larger extent than the dimensions of the electrodes the current flow is still proportional to the conductivity of the medium but is largely confined to a cross-section comparable in size to the distance between the electrodes and, in a mixture of media, to that with the highest conductivity.

While the tissues of the enclosing lumen do conduct to a small extent, capacitive current transfer is much more significant than is the case for reflux liquid within the oesophagus for instance, and by measuring the capacitive component of current flow we can effectively differentiate between tissue and reflux material.

If the distance between electrodes is very small compared with the extent of the surrounding media, the current path is effectively constrained to a very small volume that is not dependant on the size of the enclosing lumen, and the measured conductance can be used to give a good estimate of the conductivity of the media in contact with the electrodes.

By comparing this with the conductance measured across the second, longer distance, it is possible to deduce the average cross-section and hence the volume of the refluxate present.

By means of the present invention, it is possible to obtain a measurement of the impedance across both the first and second distances. Because the impedance measured across the first distance is substantially independent of the size of the conducting medium, the measurement can be used in conjunction with the impedance measurement across the second distance to deduce the average cross-section of the medium present. Since the length of the lumen is known, it is then possible to deduce the volume of the medium present.

It is known that when a current flows within a conducting medium, most flows within a volume diameter comparable with the separation of the drive electrodes. Thus, if the drive electrodes are very close together, preferably with a separation comparable to the diameter of a catheter (typically 2-4 mm), the impedance measured is a function of the conductivity of the liquid and tissues in close contact with the catheter and is effectively independent of what is present further away from the catheter within the oesophagus.

When a similar measurement is made between drive electrodes with a separation comparable with the diameter of the oesophagus, i.e 20 to 50

mm, the current flows via a much larger cross-section and the impedance per unit length is much reduced. This measurement is made between an electrode from the first pair, and an electrode from the second pair. If this impedance is compared with that measured at substantially the same time between the drive electrodes forming either the first pair or the second pair, which electrodes have a very small separation, the ratio of the impedances is a function of the effective cross-sectional area of the lumen at the point in the oesophagus where the sensor is positioned. Since the conductivity of tissue is generally low and has a large capacitive component compared to that of reflux material, this enables a reasonable estimate to be made of the volume of the material present between two sensing electrodes positioned within the lumen.

A measure of the conductivity of material closely adjacent to a pair of drive electrodes at the surface of the catheter may be obtained from each pair of drive electrodes.

Conveniently, one or more of the voltage sensing electrodes comprises further means for generating a signal independent of the drive current applied to the drive electrodes. Such a signal may be used to measure a variable such as pH.

Preferably the one or more voltage sensing electrodes comprises an antimony electrode. Alternatively, the one or more voltage sensing electrodes comprises antimony oxide.

During medical investigations it is often important to measure other parameters within a lumen, such as pH, at the same time as measuring the conductivity. If the sensing electrodes are formed from material such as antimony, they are able to simultaneously give an output induced by the

drive waveform, and another output which is independent of this waveform, that is a measure of pH.

Data relating to conductivity and pH can be combined via any suitable method such as through computer analysis to give a measure of the volume and composition of a media such as a refluxate lying between pairs of electrodes. This allows a picture of the distribution and composition of the material within the lumen to be obtained.

Preferably, the electrodes and pH sensors are connected so as to form one or more lumped circuits interrogated with AC signals. The response is analysed with complex plane analysis or time resolved methods. Voltage and current levels must be maintained within safe levels when applying the exciting signal.

By means of the present invention, it is possible to confirm the presence and approximate strength of a refluxate within the oesophagus through use of the pH sensor.

Advantageously, the device further comprises one or more pressure sensors for example pressure transducers.

A pressure transducer may be used to identify the location of the LES. When no pressure transducer is present, it is advisable to carry out prior manometry to locate the LES.

The pressure transducers may also be used to distinguish between the type of "swallows" occurring during clearance of reflux.

Advantageously, each pair of drive electrodes with their associated sensing electrodes is mounted on a housing, which housing is preferably rigid. The housing is in turn mounted on a flexible catheter. A combination of a rigid housing, and a flexible catheter allows the device to be conveniently inserted into an oesophagus.

Preferably, the device comprises a plurality of such housings positioned at spaced apart intervals along a catheter. This allows conductivity at different points within an oesophagus, the conductance between those points, and the pH of a reflux at different points to be measured.

A device according to the present invention incorporates both conductance electrodes and one or more pH sensors, which are combined in a single measurement system that can operate at one or more drive frequencies. The data can be interpreted using complex plane analysis or time resolved methods, allowing estimates of the characteristics and volume of refluxate to be made.

According to a second aspect of the present invention there is provided a method of monitoring conditions within a lumen, the method comprising the steps of:

inserting a catheter into a lumen;

measuring a first impedance (or conductance) within the lumen across a first distance;

measuring a second impedance (or conductance) within the lumen across a second distance;

the first distance being substantially equal to the diameter of the lumen, the second distance being substantially equal to the diameter of the catheter;

comparing the first impedance with the second impedance.

The invention will now be further described by way of example only with reference to the accompanying drawings in which:

Figure 1 is a schematic representation showing a plurality of electrodes on a section of a catheter forming part of a device according to the invention;

Figure 2 is a schematic representation of a second catheter forming part of a device according to the invention;

Figure 3 is a schematic representation showing the shape of a drive waveform applied to the catheter of Figure 1;

Figure 4 is a schematic representation showing the shape of the waveform output from the catheter of Figure 1 when the device is placed in a saline or tap-water solution;

Figure 5 is a schematic representation of the waveform of the output of the catheter of Figure 1 when the device has been placed in an oesophagus containing no bolus; and

Figure 6 is a schematic representation showing a typical micro-processor controlled ambulatory recorder system incorporating a device according to the present invention.

With reference to Figure 1, a device according to the present invention is designated generally by the reference numeral 2. The device comprises a catheter 4 on which is positioned a plurality of electrodes 6, 8, 10, 12, 14, 16, 18 and 20. The catheter 4 comprises two pairs of drive electrodes 22, 24. Pair 22 comprises drive electrodes electrodes 6, and 12 with associated

sensing electrodes 8 & 10. Pair 24 comprises drive electrodes 14, and 20 with associated sensing electrodes 16 & 18.

The electrodes are spaced apart by between 1 to 2 mm. The electrodes forming pair 22 are separated by the electrodes forming pair 24 by a distance of approximately 20 –60 mm.

When it is required to monitor conditions within an oesophagus, the catheter 4 is inserted into the oesophagus where measurements are to be carried out. A drive waveform is applied between electrodes 6 and 12, and also between electrodes 14 and 20. Output is measured between sensing electrodes 8 and 10, and also between sensing electrodes 16 and 18.

A drive waveform may also be applied between electrodes 6 and 20. Electrodes 12 and 14 are then not used. The output from the device then depends on the cross section of media positioned between electrodes 6 and 20. Additional measurements can be made between electrodes 8 and 18.

Referring now to Figure 2, a device according to the present invention is designated generally by the reference numeral 30. The device 30 comprises a catheter 32 which is connected via an electrical connector 34 to measuring devices for recording measurements produced by the device 30. The catheter 22 has mounted thereon drive/sensing electrode pairs 36 and 38. The device further comprises two pressure sensors 37 and 38. The electrode groups 36, 38 are separated from each other by a distance of approximately 50 mm.

Figure 4 shows the waveform output typically found when a device according to the present invention is placed in tap-water or saline.

Figure 5 shows the waveform of the output achieved when the device is positioned within an oesophagus, and part of the current path is through reflux or flesh. The result of having reflux or flesh in part of the current path is that the output waveform is degraded by capacitive coupling. The shape of the waveform is used to determine the nature of the material surrounding the sensors.

Referring to Figure 6, a system incorporating a device according to the present invention is shown. The system 40 comprises a microprocessor 42 for controlling the system and for short term storage of data. The system further comprises a computer 44 allowing long term data storage, analysis and display. The microprocessor controls one or more pulse generators 46 which drive electrodes 48. The electrodes measure the conductance of the media surrounding the catheter and are also able to measure the pH. The electrode 48 produce signals which drive AC conductance amplifiers 50 and also DC pH amplifiers 52. The device further comprises at least one pressure sensor 52 which is connected to a pressure amplifier 54. The signal produced from the electrode 48 and the pressure sensor 52 are fed via amplifiers 50, 52 and 54 to an analogue/digital converter 58. The analogue/digital converter feeds data back into the microprocessor 42, which data may be stored in the computer 44.

CLAIMS

1. A device for measuring conductance within a lumen containing conducting medium and having an average diameter, the device comprising:

   a body portion positionable within the lumen and having a body diameter;

   drive means;

   a sensor driven by the drive means comprising:

      means for applying a first electrical current across a first distance substantially equal to the body diameter;

      means for applying a second electrical current across a second distance, the second distance being greater than the first distance;

      sensing means for sensing the voltage across both the first and the second distance.

   means for measuring the impedance across both the first and second distances, and

   means for comparing the impedance across the first distance with the impedance across the second distance.

2. A device according to Claim 1 wherein the first distance is small compared to the dimensions of the lumen.

3. A device according to Claim 1 or Claim 2 wherein the drive means produces a drive waveform.

4. A device according to Claim 1 wherein the body portion comprises a catheter.

5. A device according to Claim 1 or Claim 2 wherein the means for generating the first and second electrical currents comprises first and second pairs of drive electrodes, the electrodes forming each of the first and second pairs being separated by the first distance, and the first and second pairs being separated by the second distance.

6. A device according to any one of the preceding claims wherein the sensing means comprises a voltage sensing electrode associated with each drive electrode.

7. A device according to any one of the preceding claims comprising signal means for generating a signal independent of the first electrical signal.

8. A device according to Claim 7 wherein the signal means comprises one or more voltage sensing electrodes.

9. A device according to Claim 8 wherein the one or more voltage sensing electrodes each comprises an antimony electrode.

10. A device according to any one of Claims 3 to 9 further comprising a housing mounted on the catheter on which is positioned the sensor.

11. A device according to Claim 10 wherein the housing is rigid and the catheter is flexible.

12. A device according to any one of the preceding claims comprising a plurality of sensors positioned at spaced apart intervals.

13. A method for monitoring conditions within a lumen comprising the steps of:

inserting a catheter into a lumen;

measuring a first impedance (or conductance) within the lumen across a first distance;

measuring a second impedance (or conductance) within the lumen across a second distance;

the first distance being substantially equal to the diameter of the lumen, the second distance being substantially equal to the diameter of the catheter;

comparing the first impedance with the second impedance.

14. A device substantially as herein before described with reference to the accompanying drawings.

15. A method substantially as herein before described with reference to the accompanying drawings.

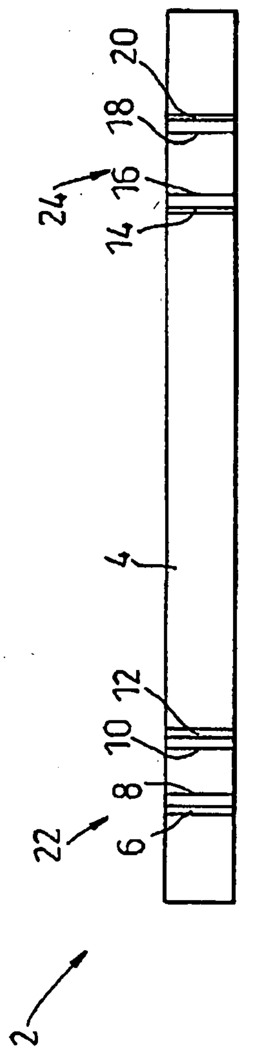


Fig. 1

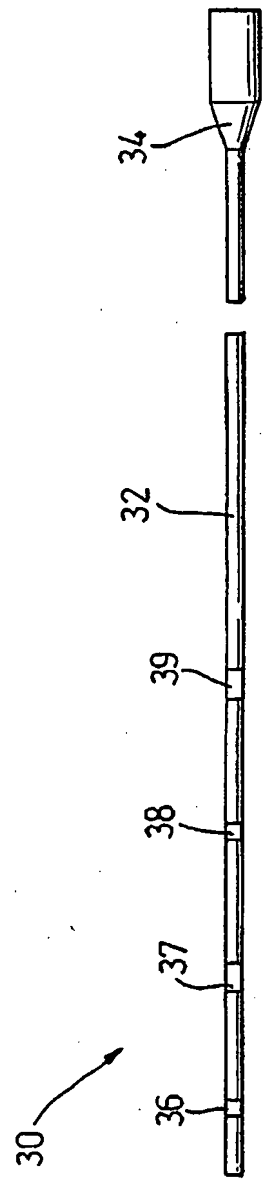


Fig. 2

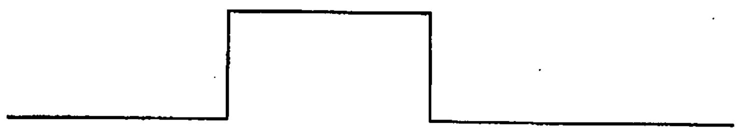


Fig. 3

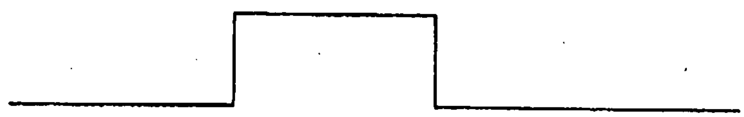


Fig. 4

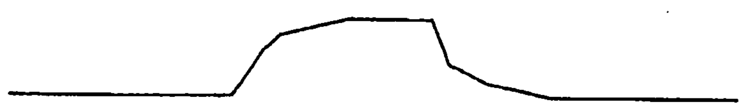


Fig. 5

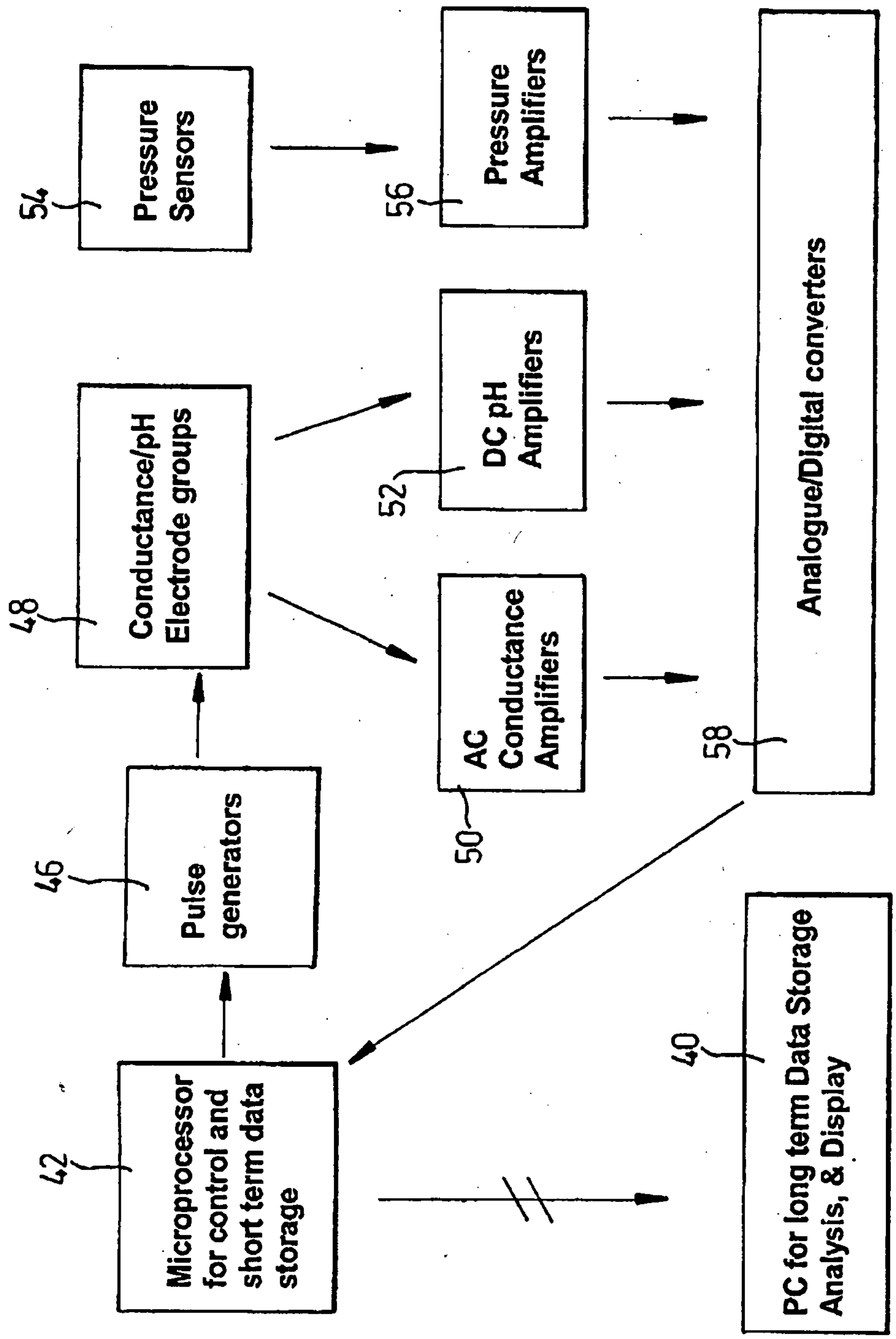

Pressure Sensors
54
Pressure Amplifiers
56
Conductance/pH Electrode groups
48
DC pH Amplifiers
52
AC Conductance Amplifiers
50
Analogue/Digital converters
58
Pulse generators
46
Microprocessor for control and short term data storage
42
PC for long term Data Storage Analysis, & Display
40

Fig. 6

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 03/01929

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 A61B5/05

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 A61B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US 5 833 625 A (ESSEN-MOLLER ANDERS) 10 November 1998 (1998-11-10) column 2, line 66 -column 3, line 45 column 4, line 62 - line 64	1-8, 10-12,14 9
X	RU 2 154 409 C (MO GORODSKOJ NI INS;TITUT SKOROJ POMOSHCHI IM N V) 20 August 2000 (2000-08-20) page 3, right-hand column, line 33 -page 4, right-hand column, line 16	1-8, 10-12,14
Y	US 4 587 975 A (SALO RODNEY W ET AL) 13 May 1986 (1986-05-13) column 3, line 25 - line 51	9

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
8 September 2003	18/09/2003
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Authorized officer Martelli, L

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Inten nal application No.
PCT/GB 03/01929

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. [X] Claims Nos.: 13,15
because they relate to subject matter not required to be searched by this Authority, namely:
Rule 39.1(iv) PCT - Method for treatment of the human or animal body by therapy

2. [ ] Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. [ ] Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. [ ] As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. [ ] As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. [ ] As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. [ ] No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

[ ] The additional search fees were accompanied by the applicant's protest.

[ ] No protest accompanied the payment of additional search fees.

Form PCT/ISA/210 (continuation of first sheet (1)) (July 1998)

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB 03/01929

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
US 5833625	A	10-11-1998	US	5479935 A	02-01-1996
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US 4587975	A	13-05-1986	NONE		

Form PCT/ISA/210 (patent family annex) (July 1992)